(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 176 731 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
30.01.2002 Bulletin 2002/05

(51) Int Cl.⁷: H04B 1/707

(21) Application number: 01000274.9

(22) Date of filing: 11.07.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 11.07.2000 US 217276 P
30.01.2001 US 772756

(71) Applicant: Texas Instruments Inc.
Dallas, Texas 75251 (US)

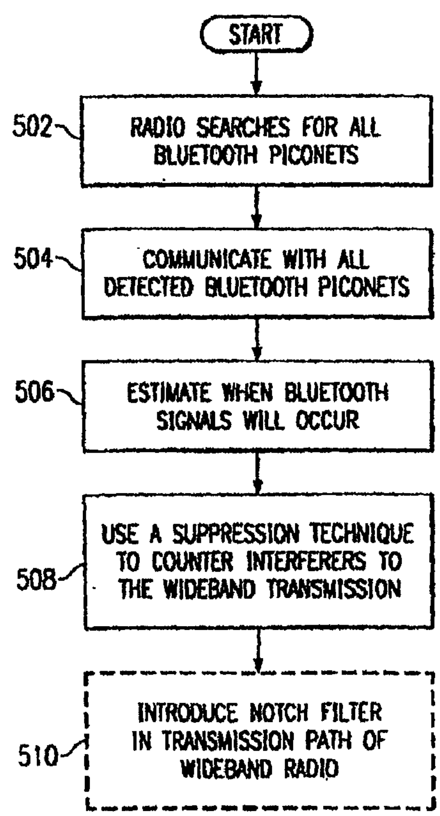
(72) Inventors:
- Nafie, Mohammed
  Richardson, Texas (US)
- Schmidl, Timothy M.
  Dallas, Texas 75243 (US)
- Anand, G. Debak
  Plano, Texas 75025 (US)

(74) Representative: Holt, Michael
Texas Instruments Ltd., EPD MS/13, 800 Pavilion Drive
Northampton Business Park, Northampton NN4 7YL (GB)

(54) Interference cancellation of a narrow band interferer in a wide band communication device

(57) Interference cancellation/suppression by a wide band radio (100) includes the steps of searching for all narrow band interferer signals such as Bluetooth signals (502). Communicating with the detected Bluetooth piconets (504). Estimating when the Bluetooth signals will occur (506) using the information received during step (504). And using a suppression technique in association with the estimations as to when/where the interfering signals will occur in order to counter the interfering signal(s). In an alternate embodiment, both the narrow band (304) and wide band (302) signals are stored (306). Then the one or more narrow band Bluetooth signal(s) (304) and decoded (308) and subtracted (308) from the wide band packet prior to it being decoded (312).

FIG. 5



EP 1 176 731 A1

Description

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates in general to the field of radio communications and more specifically to interference cancellation/suppression of a narrow band interferer in a wide band communication device.

BACKGROUND OF THE INVENTION

[0002] The operation of a wide band communication device can be severely affected by its proximity to one or more narrow band systems, in particular, if the narrow band system(s) have relatively high power. Given the increasing growth of narrow band systems such as frequency hopping (FHSS) spread spectrum systems like Bluetooth, there is a need in the art for a method and apparatus for canceling/suppressing the interference caused by such narrow band systems on a wide band system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The invention, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. 1 shows a block diagram of a dual mode radio.
FIG. 2 highlights the technique of using a notch filter on the narrow band interferer.
FIG. 3 highlights a joint wide band/narrow band detection technique.
FIG. 4 shows a block diagram of a wide band radio.
FIG. 5 shows a flow chart highlighting the steps taken using the dual mode radio shown in FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0004] Referring now to FIG. 1, there is shown a dual mode radio 100 including a wide band radio section 104 and a narrow band radio section 102. The narrow band radio section 102 in the preferred embodiment comprises a Bluetooth™ (trademark of Telefonaktiebolaget LM Ericsson Corporation) radio system. The Bluetooth system is operating in the 2.4 Giga-Hertz (GHz) ISM (Industrial Scientific Medicine) band. In a large number of countires around the world the range of this frequency band is 2400-2483.5 Mega_Hertz (MHz). Channel spacing for Bluetooth is 1 MHz and guard bands are used at the lower and upper band edges (e.g., in the United States the lower guard band is 2 MHz and the upper guard band is 3.5 MHz).

[0005] The Bluetooth radio 102 can register with, receive and decode transmissions from a Bluetooth piconet. The wide band radio 104 can for example comprise a 802.11b system, a 802.11 system, or a 802.15.3 system. In the preferred embodiment, the wide band radio 104 can comprise any radio that has a wider band than the Bluetooth radio section 102. Assuming the wide band radio 104 comprises a 802.11b system, then the wide band radio comprises a spread spectrum system which covers the 2.4 GHz band. Such a wide band radio can be used for applications such as wireless local area networks (WLAN).

[0006] In accordance with the interference suppression/cancellation technique of the preferred embodiment, the steps shown in the flowchart of FIG. 5 are performed. In step 502, the dual mode radio 100 searches for all Bluetooth piconets in its proximity using its Bluetooth radio section 102. The Bluetooth radio section 102 scans across its receive band for potential interferers. If any Bluetooth piconets are detected in the vicinity, this information is stored in the Bluetooth radio section 102 and/or in controller 106. In step 504, dual mode radio 100 will then communicate with all of the detected piconets using the Bluetooth radio section 102 and will hence receive the clock and ID of the piconet masters for each of the Bluetooth piconets detected.

[0007] The information received from the piconet masters is then stored in either the Bluetooth radio section 102 and/or controller 106 depending on the particular design of radio 100. Controller 106 can comprise any one of a number of control circuits, including microprocessors, digital signal processors (DSPs), etc. In step 504, the Bluetooth radio section 102 can simply collect the needed information from the Bluetooth master (s) in a non-registered mode (i.e., park mode) or fully register with the detected piconets depending on the system design.

[0008] The wide band radio 104 and/or controller 106 uses the clock and the ID of the Bluetooth masters received in step 504 to estimate the hopping frequency and transmission times for all of the Bluetooth transmissions in step 506. In step 508, if the wide band radio 104 receives a transmission from another wide band radio on a frequency band that overlaps one of the Bluetooth bands that had been previously detected, it will use one of the following two suppression techniques:

Notch Filter

[0009] The wide band radio 104 will place a programmable notch filter(s) in the Bluetooth band(s) that will potentially interfere with the wide band radio 104 reception of wide band signals. The notch filter(s) can be implemented digitally or in analog fashion as is known in the art. In FIG. 2 there is shown a wide band transmission 202 that has been interfered with by a narrow band Bluetooth transmission signal 204. A notch filter 206 implemented within the wide band radio 104 filters out the interfering signal Bluetooth signal 204 in order to produce the resultant signal 208. The filtered signal 208 can

then be properly decoded by the wide band radio 104. By registering with the potential interfering narrow band systems, radio 100 can add the notch filter(s) prior to even receiving the wide band transmission in some cases since the timing and hopping information for the interfering Bluetooth systems is known by radio 100.

Joint Detection

[0010] An alternative embodiment to the introduction of a filter as discussed above, is to jointly detect both the data packet that is intended for the wide band radio 104 and the Bluetooth packet(s) that have the potential of interfering with the wide band data packet. This can be done by buffering the whole packet received by the wide band radio section 104 including both the wide band 302 and narrow band 304 information as shown in block 306 of FIG. 3. Then using the Bluetooth section 102, the Bluetooth packet 304 after appropriate filtering is decoded in block 308. The Bluetooth transmission can then be subtracted from the whole packet that was received using conventional filtering or other techniques. Finally, in block 312, the wide band data packet is decoded by the wide band radio 104. As an optional step, in step 510 shown in FIG. 5, a notch filter can be placed on the wide band radio's transmitter path so that the wide band radio's transmissions do not interferer with the Bluetooth piconet that overlap (are) the wide band radio's 104 frequency band.

[0011] In a still further embodiment, instead of using a dual mode radio 100 as shown in FIG. 1, a single radio as shown in FIG. 4 is used for the wide band radio 400. In this embodiment, the wide band radio 400 can comprise as an example a 802.11, 802.11 b or 802.15.3 radio system. The wide band radio 400 includes an analog front-end 401 that takes the received signal and turns it into baseband. Once the signal is at baseband, a bank of detection circuits which in the preferred embodiment comprise digital bandpass filters 404 each of bandwidth 1 MHz are employed. Based upon the output of the filter bank, the wide band receiver's digital backend 406 can determine whether a Bluetooth interference is present in the band. If there is a Bluetooth interferer, then a notch filter similar to the previous technique described above can be used to remove the Bluetooth interferer.

[0012] The decision circuitry 402 shown in FIG. 4 can employ different algorithms to detect the presence of a Bluetooth interferer signal. The decision circuitry 402 can comprise in one example, a control circuit implemented using a microprocessor, digital signal processor, etc. which can execute a decision making algorithm. One such algorithm can monitor the output power of the different digital filters in the filter bank 404. If the output power of one or more of the digital filters is very large compared to the others, then it can be inferred that there is a Bluetooth interferer in those band(s). This information is then sent to the digital backend 406 where an appropriate filter is applied to remove the unwanted narrow band signal from the already received signal.

[0013] While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not so limited. Numerous modifications, changes, variations, substitutions and equivalents will occur to those skilled in the art without departing from the spirit and scope of the present invention.

Claims

1. A method of suppressing one or more narrow band signals that fall within the bandwidth of a wide band radio that receives wide band signals, comprising:

   (a) searching for narrow band systems which might transmit the one or more narrow band signals;
   (b) receiving information from one or more of the narrow band systems that were found in step (a); and
   (c) using the information received in step (b) in order to provide an appropriate suppression technique to suppress any of the one or more narrow band signal(s) from the wide band signal sent to the radio.

2. A method as defined in claim 1, wherein step (c) comprises:

   providing one or more notch filters in order to suppress the unwanted one or more narrow band signals.

3. A method as defined in claim 1 or claim 2, wherein step (b) comprises:

   receiving information as to when and at what frequency the one or more narrow band signal (s) will be transmitted by the one or more narrow band systems.

4. A method as defined in any preceding claim, wherein the one or more narrow band systems comprise Bluetooth systems and the narrow band signals comprise Bluetooth packets and steps (a), and (b) are performed by a narrow band radio means which is part of the wide band radio.

5. A method as defined in claim 4, wherein the narrow band radio means comprises Bluetooth radio means.

6. A method as defined in claim 4 or claim 5, wherein step (b) further comprises:

   receiving information about the clock and ID of the one or more Bluetooth system masters in

order to estimate the hopping frequency and transmission times of the Bluetooth packets.

7. A method as defined in any preceding claim, further comprising the step of:

(d) placing one or more notch filter in the transmission path of the wide band radio so that any wide band transmissions sent by the wide band radio do not affect the one or more narrow band systems.

8. A method as defined in claim 7, wherein step (d) uses the information in step (b) to determine where to place the one or more notch filter(s).

9. A method as defined in any preceding claim, wherein the wide band radio comprises narrow band radio means and wide band radio means, the wide band signal(s) are wide band packet(s) and the narrow band signal(s) are narrow band packet(s), and the wide band radio will jointly receive any wide band packet(s) and any narrow band packet(s) falling within the wide band radio's bandwidth.

10. A method as defined in claim 9, wherein the narrow band radio means comprises a Bluetooth radio system and the narrow band packet(s) are Bluetooth packet(s), and comprising the further steps of:

buffering the jointly received packet(s);
decoding the Bluetooth packet(s) found in the jointly received packet(s) using the Bluetooth radio system;
subtracting the Bluetooth packet(s) from the jointly received packet(s); and
decoding the jointly received packet(s) after the Bluetooth packet(s) have been subtracted from the jointly received packet(s).

11. A method as defined in any preceding claim, wherein step (b) is performed after the wide band radio registers with the one or more narrow band systems.

12. A wide band radio, comprising:

a wide band radio means for receiving wide band packets;
narrow band radio means for receiving packets sent by one or more Bluetooth systems that operate within the wide band radio's bandwidth, the narrow band radio means coupled to the wide band radio section; and

wherein the narrow band radio means searches for Bluetooth systems and communicates with any Bluetooth system(s) it detects, the information received from the Bluetooth system(s) is used by the wide band radio means to form an appropriate suppression technique to suppress the Bluetooth packet(s) from any wide band packet(s) received by the wide band radio means.

13. A wide band radio as defined in claim 12, wherein the wide band radio uses the information received from the one or more Bluetooth systems to set up one or more notch filters which are used to remove the Bluetooth packet(s) from the wide band packet (s) received by the wide band radio means.

14. A wide band radio as defined in claim 12 or claim 13, wherein the wide band radio means receives a packet comprising both the desired wide band packet and one or more Bluetooth packets; and

the narrow band means decodes the one or more Bluetooth packets and the wide band radio subtracts the one or more Bluetooth packets from the received packet.

15. A wide band radio as defined in claim 14, wherein the wide band radio means decodes the received packet after the one or more Bluetooth packets have been subtracted from the received packet.

16. A wide band radio, comprising:

a wide band radio means for receiving a wide band radio packet that can include one or more narrow band radio packets transmitted by one or more narrow band systems;
a plurality of filters each having an output, the plurality of filters are coupled to the wide band radio means; and
a decision circuit coupled to the outputs of the plurality of filters, the decision circuit monitors the outputs of the plurality of filters in order to determine if one or more narrow band packets are included with the wide band radio packet that is received by the wide band radio means, if one or more narrow band packets are detected, the decision circuit sends a signal to the wide band radio means to remove the one or more narrow band packet from the received wide band packet prior to further decoding of the wide band packet.

17. A wide band radio as defined in claim 16, wherein the decision circuit determines that a narrow band packet is in the wide band packet that is received by determining that the output of one of the band-pass filters has a power level above a predetermined level.

18. A wide band radio as defined in claim 16 or claim 17, wherein the one or more narrow band packets

are removed using one or more notch filters.

19. A wide band radio as defined in any of claims 16 to 18, wherein the narrow band packets comprise Bluetooth packets.

20. A wide band radio as defined in any of claims 16 to 19, wherein the wide band radio section further comprises transmitter means for transmitting wide band packets and in response to the signal provided by the decision circuit, one or more filters are added in the transmitter section's transmission path in order to minimize interfering with the one or more narrow band systems when a wide band packet is transmitted by the transmitter means.

21. A method of suppressing one or more narrow band packets that are found in a wide band packet received by a wide band radio, comprising the steps of:

(a) providing a plurality of narrow band detection circuits each one capable of detecting a narrow band packet within a portion of the wide band radio's bandwidth;
(b) determining if one of the narrow band detection circuits has detected a narrow band packet; and
(c) suppressing the one or more narrow band packets from the wide band packet if in step (b) one or more of the narrow band detection circuits has detected a narrow band packet.

22. A method as defined in claim 21, wherein the plurality of narrow band detection circuits comprises a plurality of digital filters.

23. A method as defined in claim 21 or claim 23, wherein each of the detection circuits has an output and in step (b) it is determined that one of the narrow band detection circuits has detected a narrow band packet by determining that it has a power level at its output above a predetermined level.

FIG. 1

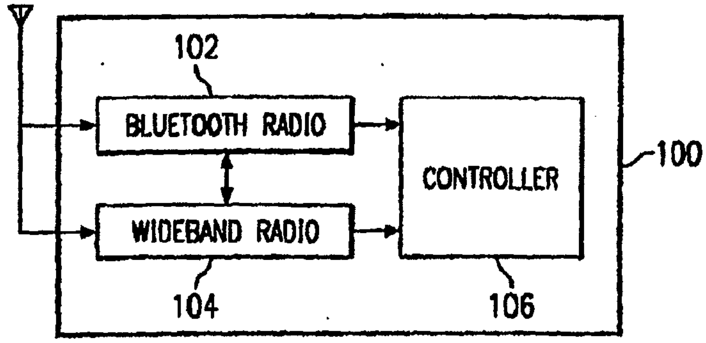


FIG. 2

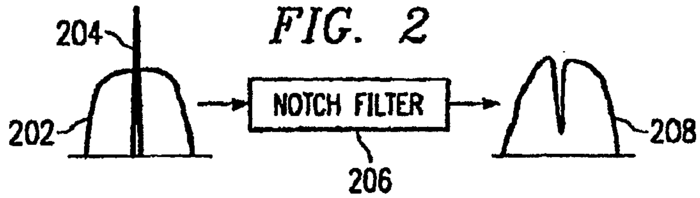
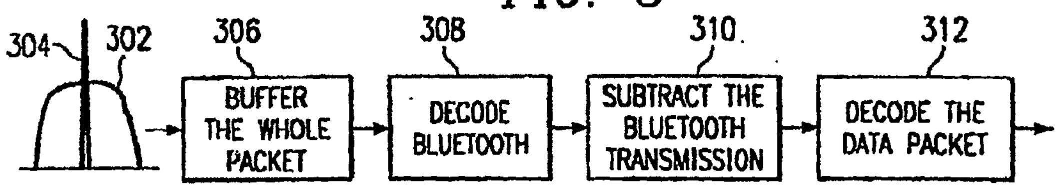


FIG. 3



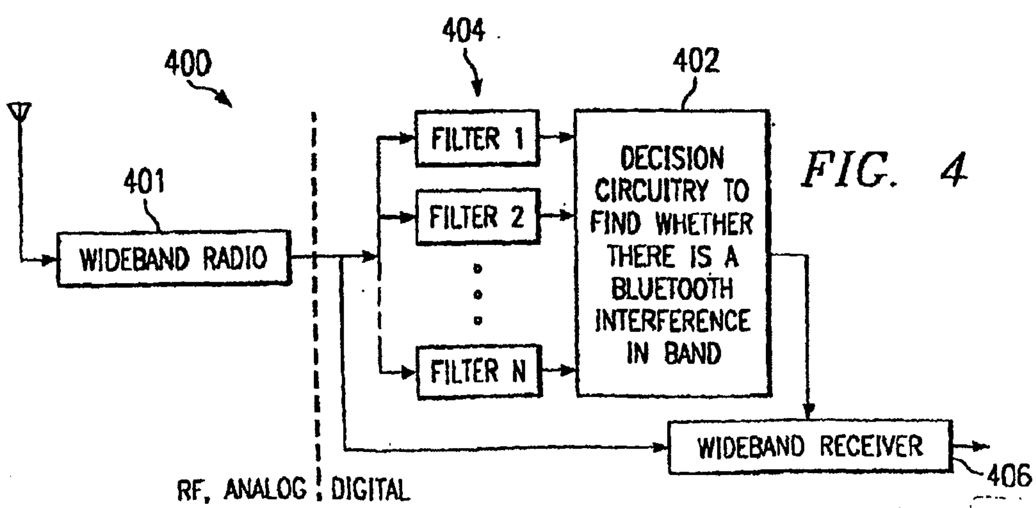
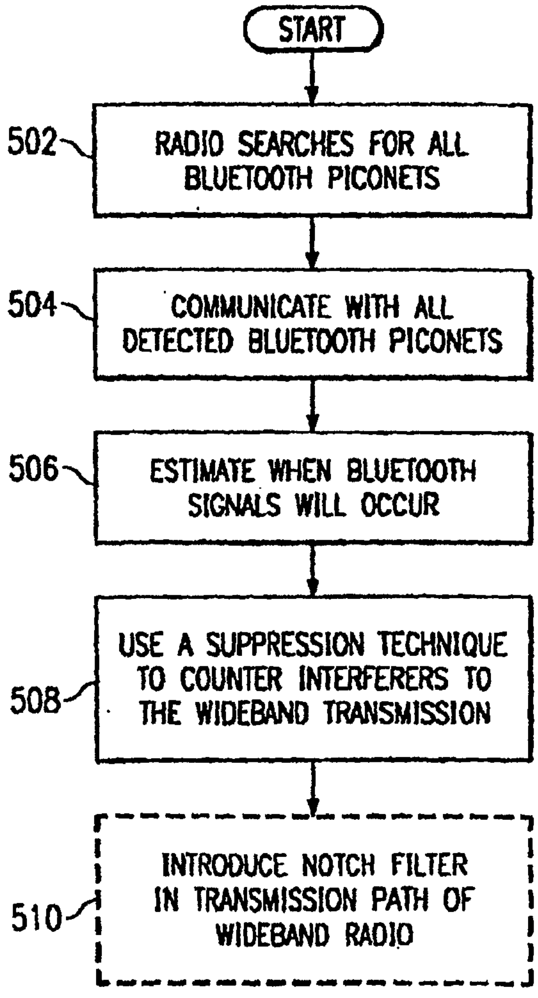


FIG. 4

FIG. 5


START
502
RADIO SEARCHES FOR ALL BLUETOOTH PICONETS
504
COMMUNICATE WITH ALL DETECTED BLUETOOTH PICONETS
506
ESTIMATE WHEN BLUETOOTH SIGNALS WILL OCCUR
508
USE A SUPPRESSION TECHNIQUE TO COUNTER INTERFERERS TO THE WIDEBAND TRANSMISSION
510
INTRODUCE NOTCH FILTER IN TRANSMISSION PATH OF WIDEBAND RADIO

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 00 0274

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
P,X	WO 00 46929 A (TOBIA MICOLINO ;WILLETTS MARK N (CA); JAGGER CHARLES E (CA); LOCKH) 10 August 2000 (2000-08-10) * abstract; figures 2-6 * * page 3, line 20 - page 5, line 2 * * page 5, line 16 - page 6, line 2 * * page 6, line 9 - page 6, line 30 * * page 8, line 25 - line 28 * * page 12, line 17 - page 13, line 11 * * claims 1,4 *	1-6,9, 10, 12-19, 21-23	H04B1/707
X	EP 0 812 069 A (SHARP KK) 10 December 1997 (1997-12-10) * abstract; figures 3A,3B,6 * * column 1, line 37 - column 2, line 2 * * column 4, line 7 - line 16 * * claims 1-4 *	1,2,12, 13, 16-18, 21,23	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
X	US 5 148 413 A (ENDO MAMORU ET AL) 15 September 1992 (1992-09-15) * abstract; claims 1,4,6; figures 11,12 * * column 3, line 27 - column 4, line 42 *	1-6,9, 10, 12-19, 21-23	H04B
X	US 5 185 762 A (SCHILLING DONALD L) 9 February 1993 (1993-02-09) * column 1, line 22 - column 2, line 61 * * claim 1 *	1,2,4,7, 8,12,13, 16,20,21	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 December 2001	Amadei, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 00 0274

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

10-12-2001

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 0046929	A	10-08-2000	AU	2426800 A	25-08-2000
			WO	0046929 A1	10-08-2000
EP 0812069	A	10-12-1997	JP	9326713 A	16-12-1997
			CN	1173101 A	11-02-1998
			EP	0812069 A2	10-12-1997
			US	6035213 A	07-03-2000
US 5148413	A	15-09-1992	JP	4270523 A	25-09-1992
US 5185762	A	09-02-1993	US	5367533 A	22-11-1994
			US	6115368 A	05-09-2000
			US	6243370 B1	05-06-2001
			US	5228053 A	13-07-1993

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82